MASTER OF SCIENCE
IN
APPLIED PHYSICS

EVALUATION OF ALTERNATIVE COMMUNICATION SCHEMES USING ENVIRONMENTALLY ADAPTIVE ALGORITHMS

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Time-varying multipath propagation in a shallow underwater environment causes intersymbol interference in high-speed underwater acoustic (UWA) communications. Combating this effect is considered to be the most challenging task requiring large adaptive filters and increasing the computational burden at the receiver end.

This thesis presents results of an in-tank experiment and data analysis performed off-line to examine, evaluate, and compare the robustness of Time-Reversal Approach to Communications (TRAC) and the Matched Environment Signaling Scheme (MESS) in different conditions, such as noise, surface waves and range changes between the receiver and transmitter. Both methods examined can environmentally adapt the acoustic propagation effects of a UWA channel. The MESS method provides a communications solution with increased computational complexity at the receiver end but gives higher data rates and is more robust to the presence of noise, surface waves, and range changes than the TRAC method. On the other hand, the TRAC method manages to accomplish secure communications with low computational complexity at the receiver.

DoD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Time Reversal Acoustics, Acoustic Communications, Acoustic Signal Processing, Acoustic Telemetry

DEFINING MINIMUM DETECTABLE TEMPERATURE DIFFERENCE (MDT) FROM MINIMUM RESOLVABLE TEMPERATURE DIFFERENCE (MRT) IN THERMAL IMAGER PERFORMANCE MODELS

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Thermal Imaging System performance prediction is typically based on the summary performance parameter Minimum Resolvable Temperature Difference (MRT), the minimum temperature difference between bars and background that allows an observer to resolve a standard four-bar target. In operational systems, MRT may be available only as a tabulated data set. For detection of smaller, distant and unresolved targets, the appropriate measure may be the Minimum Detectable Temperature Difference (MDT) defined for a uniform square target against a uniform background.

This study addressed the calculation of MDT from data derived for the MRT curve. A transfer function was developed in terms of system engineering parameters for derivation of MDT from MRT and evaluated using three analytical thermal imager performance models. This method produced favorable results for spatial frequencies below the resolution cutoff limit. Beyond the resolution limit, a transfer function method using spatial frequency independent resolution parameters and a curve-fit method for measured MRT data that employs randomly selected constants were evaluated. These methods show promise for using MRT parameters to evaluate MDT beyond the cutoff and the curve-fit proved a good approximation for MDT data beyond the cutoff spatial frequency.

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DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Thermal Imagers, Minimum Detectable Temperature Difference (MDTD), Minimum Resolvable Temperature Difference (MRTD)

THE NPS SMALL ROBOTIC TECHNOLOGY INITIATIVE, MAN-PORTABLE ROBOTS FOR LOW INTENSITY CONFLICT

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The Naval Postgraduate School's Small Robotic Technology (SMART) Initiative is an ongoing research effort within the Combat Systems Science and Technology Curriculum that engages in forward-looking applications of small robotic technology for military employment. The immediate goal of which is to develop a multipurpose robotic platform that is capable of hosting varied sensor packages for military research. This thesis successfully accomplished initial background research and integration of a low cost, lightweight, all-terrain, robotic vehicle to fulfill this requirement. The areas of robotic investigation included: research and procurement of a Foster Miller Lemming tracked vehicle; the selection of a robust, network enabled, real-time microcontroller called the ipEngine; selection of Differential GPS as a highly accurate autonomous vehicle positioning technique; and the development of the ipEngine software environment for integration and testing of the microcontroller's wireless interfacing. Wireless communication tests using TCP/IP sockets, serial communication, telnet and a common Internet Web Browser validated the ability to remotely operate the vehicle under both direct and autonomous control. Ultimately, this thesis laid the foundation for follow-on NPS students to research and integrate varied robotic sensing techniques, including synthetic array seismic sonar's and chemical detection devices, and to participate in cooperative research with other military laboratories.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics, Sensors, Ground Vehicles, Robotics

KEYWORDS: Robotics, Autonomous, Micro-Controller, Embedded Processor, Differential GPS, FPGA, ipEngine, Man-portable

CONSTRUCTION AND TESTING OF A MODERN ACOUSTIC IMPEDANCE TUBE

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The acoustic impedance of a material describes its reflective and absorptive properties. Acoustic impedance may be measured in a wide variety of ways. This thesis describes the construction and testing of an acoustic impedance measurement tube which employs modern Fourier Transform techniques. Two

methods are employed for acoustic impedance measurement using this apparatus. One technique uses a two-microphone continuous excitation method and the other uses a single microphone transient excitation method. Simple acoustic theory is used to derive equations for both methods. MATLAB computer programs are developed using these equations, to provide graphical results of acoustic impedance measurements over a frequency range for a given material, from raw data. A procedure is subsequently developed for using this apparatus to make acoustic impedance measurements. The performance of this device is evaluated by making measurements utilizing both methods on three sample materials and also with the end of the tube open to the atmosphere (referred to as an open tube measurement). The open tube measurements are compared with theoretical values. The results using both approaches compared favorably with the open tube theoretical values. Additionally both approaches agreed reasonably well with each other for the three sample materials. Performance at frequencies below 500 Hz, however, yielded deficient results, indicating a need for development of a filter for better accuracy.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Acoustic Impedance Measurement, Acoustic Impedance Tube, Reflection

ENERGETIC ELECTRON GENERATION BY FORWARD STIMULATED RAMAN SCATTERING USING 0.35 AND 0.53 MICRON LASER LIGHT IN A PLASMA

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This research investigates the use of high-powered lasers to produce 50-100 keV x-ray sources for applications for programs such as Stockpile Stewardship and nuclear weapons effects testing (NWET). To produce these x-r;ay sources requires irradiating targets with intense laser light to efficiently generate high-energy electrons. Stimulated Raman scattering (SRS) of intense laser light produces electron plasma waves, which in turn generate high-energy electrons. To make a high-energy x-ray source, the maximization of this laser-driven instability is desired. Using computer simulations, we show that forward SRS can grow by using a combination of frequency-tripled and a “seed” beam of frequency doubled laser light in a plasma of the appropriate density. Electron plasma waves with a high phase velocity are produced, which trap electrons and accelerate them to high energy. These energetic electrons will in turn generate high energy x-rays via collisions with nearby dense material. By adjusting the angle between the 0.35 μm and 0.53μm laser beams, the characteristic temperature of the heated electrons (and the x-rays) can be varied. We show one and two-dimensional simulations and illustrate the important role that laser-driven ion fluctuations play.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Stockpile Stewardship Program, Nuclear Weapons Effect Testing)

KEYWORDS: Laser-Plasma Interactions, Stimulated Raman Scattering, Plasma Instabilities

DETONABILITY OF HYDROCARBON/AIR MIXTURES USING COMBUSTION ENHANCING GEOMETRIES FOR PULSE DETONATION ENGINES

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This research studied combustion enhancing geometries and shock reflection on generating a hydrocarbon/air detonation wave in a combustion tube. Ethylene was used as a baseline fuel to determine the preferable geometries. Propane was then used in later testing because of its combustion similarities with heavy hydrocarbon fuels such JP5, JP8, and JP10. Three criteria were used to measure the effectiveness of the combustion enhancing geometries: ability to generate a detonation, wave speed, and time for shock formation. The evaluated geometries included flow-restricting orifice plates and a Schelkin spiral. The shock reflection was accomplished by a vertical fence (large orifice) placed in the last fourth of the tube length. The optimum geometry was found to be the orifice plate used in conjunction with the spiral. Detonations occurred when using ethylene in this configuration, but did not develop when using propane. Because propane's overall reaction rate is slower than that of simpler fuels, more large- and small-scale turbulence to further enhance combustion needs to be generated to create a detonation wave in a short distance when using complex hydrocarbons, such as propane.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Deflagration to Detonation Transition, DDT

PSPICE MODELING AND PARAMETRIC STUDY OF MICROBOLOMETER THERMAL DETECTORS

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The operation of a bolometer thermal sensor is analogous to that of a charging capacitor in a generic RC circuit. As such, circuits containing bolometers can be analyzed with standard circuit simulation programs such as PSPICE. This thesis deals with the development of a bolometer model by using PSPICE with the aid of Analogue Behavior Modeling (ABM) capability, which allows the user to program circuit components with basic mathematical functions. The predictions of the model were found to be in good agreement with the reported data of an experiment previously conducted, which demonstrates the accuracy of the model. The model was used to design a self-heating compensated thermal sensor with enhanced signal integration capability to improve the signal-to-noise ratio. We believe the model can be used to analyze any circuit containing bolometers to optimize the performance.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Microbolometer, Bolometer, Thermal, Sensor, PSPICE, Computer Modeling, Thermal Imaging

EXPERIMENTAL STUDIES OF TWO-WAY SINGLE ELEMENT TIME-REVERSAL IN A NOISY WAVEGUIDE

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As the United States Navy considers operation closer to shore, it must account for the impact of shallow water ocean environments on the performance of active sonar. Multi-path propagation and high ambient noise in these areas pose a unique detection challenge for current sonar systems. A possible solution for this problem involves the use of processing that is actually enhanced by multi-path propagation, and can perform in the presence of in-band noise. Time-Reverse Acoustics (TRA) has been used with many transducer elements to focus acoustic energy in a very small region. Used as a single element active sonar, it can focus the return of an active pulse at the receiver location.

To test the performance of a TRA-based sonar in the presence of noise, ultrasonic signals were used in a laboratory waveguide, so that the scale of wavelength to water depth approximates a shallow channel with a flat, lossy bottom. Several sequences of a traditional sinusoidal pulse and the time-reversed reception were performed with varying noise levels. The gain in detection signal-to-noise ratio (SNR) was on average 7.3 ± 0.8dB using TRA. Further, the TRA processing provided a noticeable detection when noise had completely obscured the reception of the initial pulse.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Time Reverse Acoustics, Active Sonar, Signal-to-Noise Ratio (SNR), Waveguide

FEASIBILITY OF PARAMETRIC EXCITATION OF ACOUSITC RESONATORS

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This thesis examines the feasibility of parametrically exciting a mode of an acoustic resonator. Such excitation may result in substantially larger amplitudes than by direct excitation, and would thus be useful in acoustic evices that require high-amplitude standing waves. Parametric excitation of a mode occur if the natural frequency is modulated at twice its value, and if the drive amplitude is above a threshold value due to dissipation. It is theoretically shown to be possible to excite the fundamental longitudinal mode of a pipe of any length filled with sulfur hexafluoride if the length is modulated with an Eletrovoice EVX-150A driver. For carbon dioxide, excitation is predicted to occur if the pope is longer than 1.2 meters. Also investigated is parametric excitation of the fundamental radial mode of a cylindrical cavity by modulating the height and thus the temperature. In this case, no driver was found to be capable of exceeding the threshold, regardless of the gas. Use of an electromagnetic wave source to modulate the temperature was also considered as a mans of parametriclly exciting the fundamental radial mode. Preliminary investigations show that sufficient heat conduction cannot occur over an acoustic cycle, indicating that this method is infeasible.

DoD KEY TECHNOLOGY AREA: Other (Acoustics)

KEYWORDS: Parametric Excitation, Acoustic Resonator, Acoustics